OPTIMIZATION OF LIGHT MEASUREMENTS FOR A LOW ENERGY PLASMA

A.J. Halstead, J. L. Zirnheld
Energy Systems Institute, University at Buffalo, 312 Bonner Hall
Buffalo, New York, 14260
M.J. Donadio
RDECOM-ARDEC, Advanced Energy Armament Systems Center
Bldg. 65N, Picatinny Arsenal, NJ 07806

Abstract

Transient light measurements can be a valuable characteristic to know when measuring a low energy plasma phenomenon. In this particular study, the light to be measured arose from plasma that is being generated on the surface of a metallized polypropylene film strip. The source of this plasma was the metallization being excited by the application of an impulse voltage of up to 2500 V. This impulse voltage yielded the energy required to liberate a small volume of metallization off of the strip of polypropylene film. The polypropylene film had been altered in such a way that the liberation of the metallization occurred in a precise physical location on the film. Even though light successfully emanated from the control location, other discharges occurred on the metallization and contributed to the light intensity measured. This paper will discuss the methods used to measure consistently the transient luminous intensity of a low energy plasma in the infrared spectrum.

I. INTRODUCTION

Surface flashover, though normally associated as a destructive force, can be used to advantage when controlled properly [1,2]. Studies are being performed to investigate the behavior of the phenomenon of surface flashover and develop techniques to control its behavior. As part of this research, studies of the nature of the plasma generated from a high voltage pulse through metallized polypropylene film are being performed. Of particular relevance to this work was the nature of the light that was emanated from the flashover phenomenon. Techniques to optimize the measurement of the light are discussed in the hopes of obtaining an understanding of all aspects of the plasma resulting from surface flashover technologies.

II. EXPERIMENTAL SETUP

Infrared photodiodes were utilized as a means of measuring the relative intensity of the light emanating from the flashover initiation. Infrared photodiodes offer sufficiently fast response times (1 ns) to measure the pulse waveforms of this class of surface flashover phenomena. PNZ300 silicon PIN photodiodes were chosen for their fast response times and narrow beam angles. Figure 1 shows the spectral response of the photodiodes.

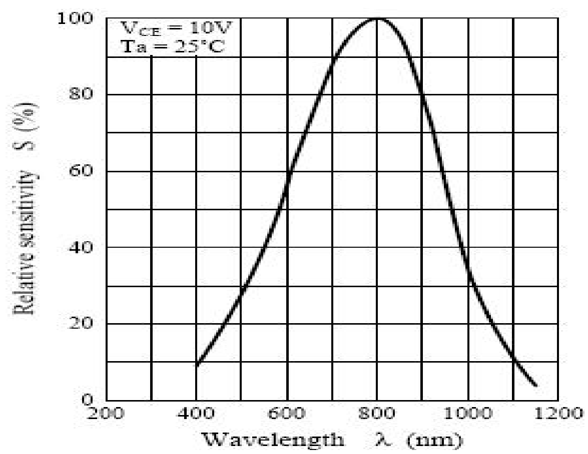

Figure 1. Spectral response of PNZ300 photodiode [3]

The PNZ300 photodiodes are particularly sensitive in the infrared region. A general schematic diagram of the photodiode setup is shown in Figure 2.

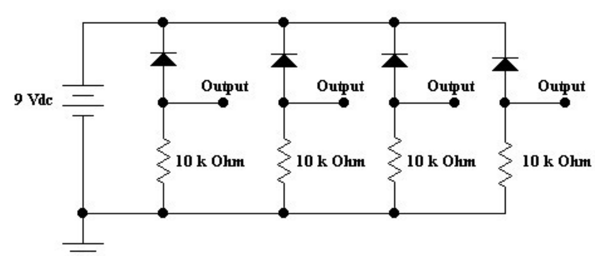

Figure 2. Photodiode schematic in flashover experiments

The photodiodes used a 9 V_{dc} power source and were calibrated to produce the same output voltage given equal lighting conditions. The resistor values shown in the schematic were altered to accurately calibrate the relative sensitivities of the photodiodes. This ensured that the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2005**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Optimization Of Light Measurements For A Low Energy Plasma**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Energy Systems Institute, University at Buffalo, 312 Bonner Hall Buffalo, New York, 14260**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002371. 2013 IEEE Pulsed Power Conference, Digest of Technical Papers 1976-2013, and Abstracts of the 2013 IEEE International Conference on Plasma Science. IEEE International Pulsed Power Conference (19th). Held in San Francisco, CA on 16-21 June 2013., The original document contains color images.

14. ABSTRACT
Transient light measurements can be a valuable characteristic to know when measuring a low energy plasma phenomenon. In this particular study, the light to be measured arose from plasma that is being generated on the surface of a metallized polypropylene film strip. The source of this plasma was the metallization being excited by the application of an impulse voltage of up to 2500 V. This impulse voltage yielded the energy required to liberate a small volume of metallization off of the strip of polypropylene film. The polypropylene film had been altered in such a way that the liberation of the metallization occurred in a precise physical location on the film. Even though light successfully emanated from the control location, other discharges occurred on the metallization and contributed to the light intensity measured. This paper will discuss the methods used to measure consistently the transient luminous intensity of a low energy plasma in the infrared spectrum.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

voltage readings of each photodiode were consistent in relation to each other.

The flashover sources for these experiments were 30.48 cm x 1.905 cm capacitor grade, metallized polypropylene film samples. A solid state pulser utilizing a capacitive discharge through an NMOS controlled thyristor generated the 2500 V narrow-width pulse of energy to initiate the flash through the polypropylene film samples. The film geometries were altered by removing metallization in select areas to form concentrated areas of light emanation during flashover. A picture of a sample of the film is shown in Figure 3.

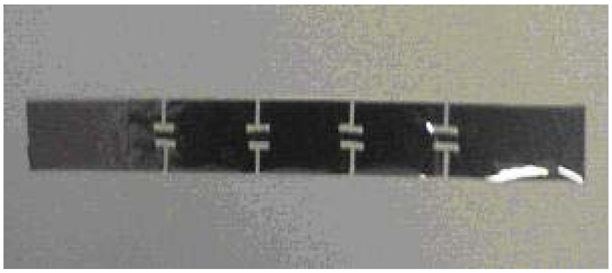

Figure 3. Example of polypropylene film sample with geometric alteration

The film samples were placed under a non-conductive framework to position the infrared photodiodes over the bottleneck areas of flashover concentration. The framework was designed to accommodate up to four photodiodes in various positions over the polypropylene film samples. However, only two photodiodes were used in these experiments. Only two photodiodes were used to allow for the comparison of relative light intensity readings with current and voltage waveforms collected on the 4-channel oscilloscope. The photodiodes were embedded into the framework so as to minimize the reception of ambient light. Thus, the setup for the experiments was designed in such a way as to maximize the infrared light-gathering potential of the system. Ideally, the light emitting from each of the bottlenecks was channeled directly to the corresponding photodiode. Figure 4 shows a model of the photodiode framework. The infrared photodiodes were placed in the holes in the base-plate of the structure and coaxial connectors were used to interface the photodiodes with the oscilloscope.

A Tektronix 4-channel digital oscilloscope was used to take the measurements for the experiments. One photodiode was placed over a bottleneck at each end of the polypropylene film. By measuring the luminous intensity at each end of the film, accurate measures of relative energy could be determined as energy is directly proportional to relative intensity.

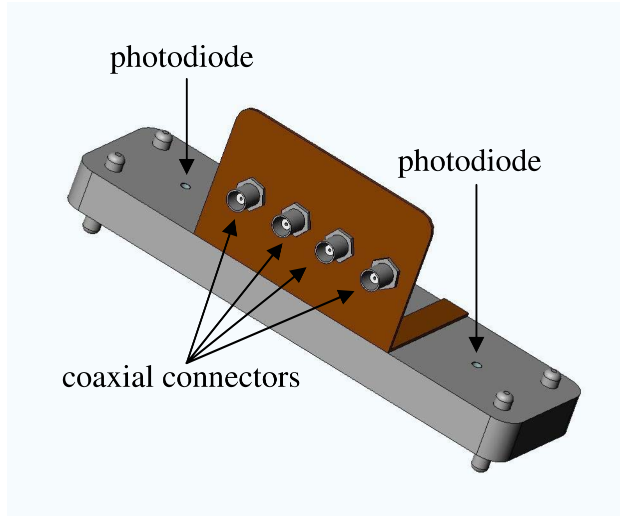

Figure 4. Setup of framework for photodiodes

The transient waveforms of these photodiodes were observed on channels 1 and 4 of the oscilloscope. Channel 2 was used to measure the current of the flashover utilizing a Pearson type 411 current probe with a 0.1 Volts/Ampere output. Channel 3 used a Tektronix P6015 voltage probe with a 1000:1 attenuation ratio to measure the voltage of the system.

III. OPTIMIZATION TECHNIQUES

Initial tests were performed with the infrared photodiodes embedded into the framework over the film samples to provide cylindrical channels for the emanating light to focus in. Figure 5 shows how the light from the flashover was ideally channeled to the photodiodes in the framework.

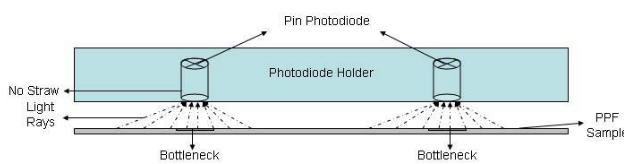

Figure 5. Ideal scenario for light gathering

However, these channels were in excess of 1.27 cm above the sources of light. Because of this it was possible that, although much of the light was channeled to the photodiodes, a significant amount of light could still be scattered to other areas. Thus, several techniques were developed in an attempt to optimize the light measurement efficiency of the system.

The first technique utilized to optimize the measurements was to extend the light-gathering channels closer to the sources of light. Placing small tubes in the currently existing channels allowed for the creation of new channels that extended within close proximity (less than 0.635 cm) of the bottlenecks on the film. This alteration in the physical setup maximized the amount of light received by the photodiodes. A model of the setup

with extended channels is shown in Figure 6. Figure 7 shows how the light was gathered with the extended light-gathering channels.

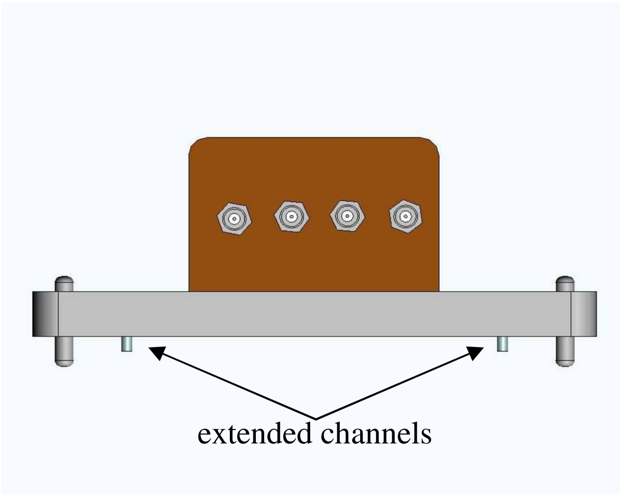

Figure 6. Photodiode framework with extended channels

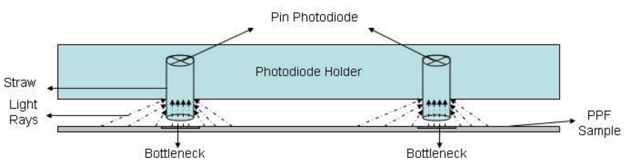

Figure 7. Scenario for light gathering with extended channels

The second improvement made to the system was placing black adhesive on the underside of the photodiode framework. To obtain consistent measurements from each of the photodiodes, the minimization of reflection was necessary. Reflections from one light source could bounce to the photodiode on the opposite end, thus providing inaccurate results. The black adhesive on the underside of the photodiode framework absorbed most of the light emitted from the flash that did not get channeled to the photodiodes. Without this absorption, the light could have reflected off of the framework and the metallized film sample, creating unexpected transients in the photodiode waveforms. Because of the unpredictable nature of these reflections, it was desirable to minimize their effects on the measurements taken.

IV. EXPERIMENTAL RESULTS

Experiments were performed under each of the aforementioned conditions: first with no alterations to the setup (setup #1), then with extended channels (setup #2), followed by extended channels as well as absorbing black adhesive (setup #3). For all experiments, 2500 V was discharged from the pulser through the metallized polypropylene film samples. Measurements of light intensity at each end of the film sample were taken along with the current through the film and voltage measurements of the system. The photodiode measurements are of most importance for this study as the consistency of these measurements provides an indication of the optimization of the system.

For the first set of experiments, the setup shown in Figure 4 without extended channels and no black adhesive was utilized. A large number of experiments yielded an average photodiode reading of 4.74 V_{dc} for the bottleneck near the negative electrode (photodiode 1) and 5.36 V_{dc} for the bottleneck near the positive electrode (photodiode 4). The standard deviation is used as a measure of the consistency of the measurements. For this setup, the standard deviations for photodiodes 1 and 4 were 2.17 V_{dc} and 1.92 V_{dc} respectively. This indicates that the results were rather inconsistent from one test to another. It was determined that too much light may have been scattered and/or was not being channeled to the photodiodes properly.

The second set of experiments used tubes to extend the channels for the photodiodes closer to the sources of light. The average reading for photodiode 1 in this set of experiments was 4.69 V_{dc}, and the average for photodiode 4 was 4.20 V_{dc}. The standard deviations were 1.59 V_{dc} and 2.24 V_{dc} respectively. As was the case in the previous set of experiments, the standard deviation of the measurements is too high for consistent results. Extending the channels closer to the sources of light did not help in providing consistent results.

The last technique employed was to couple the extended channels with black adhesive on the underside of the photodiode framework to prevent reflections. Measurements were again taken by photodiodes at each end of the polypropylene film samples. The average readings of photodiodes 1 and 4 were 4.49 V_{dc} and 4.68 V_{dc}. The standard deviations were 1.49 V_{dc} and 2.17 V_{dc}. The consistency of results between tests remained quite low. Table 1 summarizes the results obtained from the experiments with each of the three setups.

Table 1. Summary of voltages and standard deviations of photodiode measurements

	Photodiode 1		Photodiode 4	
Setup #	Average Voltage (V)	Standard Deviation (V)	Average Voltage (V)	Standard Deviation (V)
1	4.74	2.17	5.36	1.92
2	4.69	1.59	4.2	2.24
3	4.49	1.49	4.68	2.17

V. CONCLUSIONS

The consistency from one test to another in all three setups did not provide an indication as to which setup

provides for the most accurate results. After the first set of experiments, it was determined that too much light was escaping and not being channeled to the photodiodes. The second setup sought to solve this by extending the light-gathering channels of the photodiodes closer to the sources of light. Again, the results were rather inconsistent from one test to another. The third setup utilized black adhesive on the underside of the photodiode framework to minimize reflection. This technique also did not sufficiently improve the consistency from one test to another.

There are several possible reasons that inconsistent results persisted after several optimization methods were performed. The first is that the generation of the plasma flash may be quite different from one test to another. Although as many variables as possible are kept consistent from one test to another by taking extreme care in the sample manufacturing and handling process, unforeseen conditions may be altering the flash. For example, the thickness of the samples may vary slightly as the film samples are cut from a large roll. Slight differences in thickness may result in changes in electron flow, thus altering the nature of the flashover. In this case, it may not be the measurement technique that needs optimization, but the processing of the samples or control of experimental conditions.

The second possible reason is that the lack of a precise positioning system of the photodiodes over the bottlenecks could alter the results from one trial to another. Unless the light-gathering channels can be positioned precisely over both bottlenecks in all tests, the resulting measurements may not be consistent. Future work toward a precision positioning system is necessary to determine if this is indeed the cause for inconsistency.

VI. ACKNOWLEDGEMENTS

Effort sponsored by the U.S. Army's Advanced Energy Armament Systems Center at RDECOM-ARDEC, under grant number DAAE30-03-1-0200. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the Department of Defense or the U.S. Government. Distribution statement A. Approved for public release.

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